

+

10/10/00  
JC803 U.S. PTO

# UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.

35.G2657

First Named Inventor or Application Identifier

SHUICHI KOBAYASHI

Express Mail Label No.

## APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

## ADDRESS TO:

Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

1. ☒ Fee Transmittal Form  
(Submit an original, and a duplicate for fee processing)
2. ☐ Applicant claims small entity status.  
See 37 CFR 1.27.
3. ☒ Specification Total Pages
4. ☒ Drawing(s) (35 USC 113) Total Sheets
5. ☒ Oath or Declaration Total Pages
- a. ☒ Newly executed (original or copy)
- b. ☐ Copy from a prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 17 completed)  
[Note Box 6 below]
- i. ☐ **DELETION OF INVENTOR(S)**  
Signed Statement attached deleting  
inventor(s) named in the prior application, see  
37 CFR 1.63(d)(2) and 1.33(b).
6. ☒ Application Data Sheet See 37 CFR 1.76

7. ☐ CD-ROM or CD-R in duplicate, large table or Computer  
Program (Appendix)
8. ☐ Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all necessary)
- a. ☐ Computer Readable Form (CRF)
- b. Specification Sequence Listing on:
- i. ☐ CD-ROM or CD-R (2 copies); or
- ii. ☐ paper
- c. ☐ Statements verifying identity of above copies

JC760 U.S. PTO  
09/685042  
10/16/00

## ACCOMPANYING APPLICATION PARTS

9. ☒ Assignment Papers (cover sheet & document(s))
10. ☐ 37 CFR 3.73(b) Statement ☐ Power of Attorney  
(when there is an assignee)
11. ☐ English Translation Document (if applicable)
12. ☒ Information Disclosure ☒ Copies of IDS  
Statement (IDS)/PTO-1449 Citations
13. ☒ Preliminary Amendment
14. ☒ Return Receipt Postcard (MPEP 503)  
(Should be specifically itemized)
15. ☐ Certified Copy of Priority Document(s)  
(if foreign priority is claimed)
16. ☐ Other: \_\_\_\_\_

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No. \_\_\_\_/\_\_\_\_  
Prior application information: Examiner \_\_\_\_\_ Group/Art Unit: \_\_\_\_\_

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

## 18. CORRESPONDENCE ADDRESS

☒ Customer Number or Bar Code Label  (Insert Customer No. or Attach bar code label here) or ☐ Correspondence address below

NAME

Address

City

State

Zip Code

Country

Telephone

Fax

+

CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS (37 CFR 1.16(e))	24-20 =	4	X \$ 18.00 =	\$ 72.00
	INDEPENDENT CLAIMS (37 CFR 1.16(b))	2-3 =	0	X \$ 80.00 =	\$ 0.00
	MULTIPLE DEPENDENT CLAIMS (if applicable) (37 CFR 1.16(d))			\$270.00 =	\$ 270.00
				BASIC FEE (37 CFR 1.16(a))	\$ 710.00
			Total of above Calculations =		\$ 1052.00
	Reduction by 50% for filing by small entity (Note 37 CFR 1.9, 1.27, 1.28).				
	TOTAL =				\$ 1052.00

19. Small entity status

- a. ☐ A small entity statement is enclosed
- b. ☐ A small entity statement was filed in the prior nonprovisional application and such status is still proper and desired.
- c. ☐ Is no longer claimed.

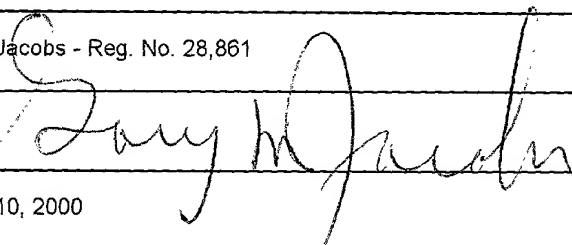
20. ☒ A check in the amount of \$1052.00 to cover the filing fee is enclosed.

21. ☒ A check in the amount of \$ 40.00 to cover the recordal fee is enclosed.

22. The Commissioner is hereby authorized to credit overpayments or charge the following fees to Deposit Account No. 06-1205:

- a. ☒ Fees required under 37 CFR 1.16
- b. ☒ Fees required under 37 CFR 1.17
- c. ☐ Fees required under 37 CFR 1.18.

**SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED**

NAME	Gary M. Jacobs - Reg. No. 28,861
SIGNATURE	
DATE	October 10, 2000

DSG\GMJ\cmv

INVENTOR INFORMATION

Inventor One Given Name: Shuichi

Family Name: KOBAYASHI

Postal Address Line One: 28-1-302, Chigusadai, Aoba-ku

City of Residence: Yokohama-shi

State or Province of Residence: Kanagawa-ken

Country of Residence: Japan

Citizenship Country: Japan

CORRESPONDENCE INFORMATION

Correspondence Customer Number: 05514

Fax: (212) 218-2200

APPLICATION INFORMATION

Title Line One: DIFFRACTION OPTICAL DEVICE AND OPTICAL SYSTEM

Title Line Two: INCLUDING THE SAME

Total Drawing Sheets: 7

Formal Drawings?: Yes

Application Type: Utility

Docket Number: 35.G2657

Secrecy Order in Parent Appl.?: No

REPRESENTATIVE INFORMATION

Representative Customer Number: 5514

PRIOR FOREIGN APPLICATIONS

Foreign Application One: 11-290057

Filing Date: 10-12-1999

Country: JAPAN

Priority Claimed: Yes

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: )  
 : Examiner: Not yet assigned  
 Shuichi Kobayashi )  
 : Group Art Unit: Not yet assigned  
 Application No.: Not yet assigned )  
 :  
 Filed: October 10, 2000 )  
 :  
 For: DIFFRACTION OPTICAL )  
 DEVICE AND OPTICAL :  
 SYSTEM INCLUDING SAME ) October 10, 2000

Commissioner for Patents  
 Washington, D.C. 20231

PRELIMINARY AMENDMENT

Sir:

Prior to examination, please amend the application as follows:

IN THE CLAIMS

Please amend Claims 5, 7, 9, and 10 as follows:

Claim 5

Line 2, change "claims 1 to 4" to --Claims 1 to 3--.

Claim 7

Line 2, change "any one of Claims 1 to 6" to --any one of Claims 1 to 3--.

Claim 9

Line 1, change "Claim 7 or 8" to --Claim 7--.

Claim 10

Line 1, change "Claim 7 or 8" to --Claim 7--.

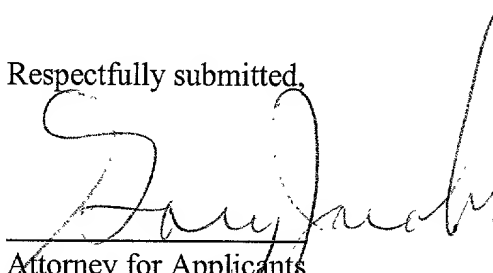
Remarks

Claims 1 through 10 are pending in the application. Claims 5, 7, 9, and 10 have been amended so that no multiple dependent claim depends on another multiple dependent claim.

Consideration and an early allowance are respectfully solicited.

Applicants' undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,



Attorney for Applicants  
Registration No. 28,861

FITZPATRICK, CELLA, HARPER & SCINTO  
30 Rockefeller Plaza  
New York, New York 10112-3801  
Facsimile No.: (212) 218-2200

TITLE OF THE INVENTION

DIFFRACTION OPTICAL DEVICE AND OPTICAL SYSTEM INCLUDING SAME

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a diffraction optical device and an optical system including the diffraction optical device. More particularly, the present invention is intended to realize a diffraction optical device capable of suppressing the occurrence of flare light due to diffracted light of unnecessary orders, and an optical system including the diffraction optical device.

Description of the Related Art

Hitherto, there is known a method for reducing chromatic aberration by combining plural kinds of glass materials with each other. Another advanced method for reducing chromatic aberration by providing a diffraction optical device, which develops a diffraction action, on a lens surface or in part of an optical system is disclosed in the literature of SPIE Vol. 1354 International Lens Design Conference (1990), Japanese Patent Laid-Open No. 4-213421 and No. 6-324262, U.S. Patent No. 5,044,706, etc. This method for reducing chromatic aberration is based on a

physical phenomenon that a refracting surface and a diffracting surface in an optical system develop chromatic aberration in opposing directions for the light of a certain reference wavelength.

5 Further, providing a diffraction optical device is greatly effective in reducing the aberration of an optical system because the diffraction optical device is able to function similarly to an aspherical lens by changing the grating pitch so that diffractive power is partly changed.

10 While in a refraction optical system one ray of light remains as it is after being refracted, one ray of light is divided into plural rays of diffracted light of different orders in a diffraction optical system. In the case of employing a diffraction optical device in a lens system, 15 therefore, the structure of a grating must be determined such that light in the wavelength range to be used is concentrated in one particular order (referred to also as "design order" hereinafter). By concentrating diffracted light in the design order, diffracted light of other orders 20 has a low intensity and can be regarded as being absent if the intensity is zero.

If rays of diffracted light of orders other than the design order are present, those light rays are focused in positions different from that in which the ray of diffracted 25 light of the design order is focused, and hence generate

flare light that is out of focus with respect to the designed image plane. For this reason, in an optical system utilizing the diffraction effect, it is important to pay due consideration to a spectral distribution obtained with the diffraction efficiency for diffracted light of the design order and behaviors of diffracted light of orders other than the design order. Thus, to effectively utilize the color-aberration compensating effect of a diffraction optical device having the above-mentioned properties, it is required that the diffraction efficiency for diffracted light of the design order is sufficiently high over the entire wavelength range to be used, and diffracted light is substantially concentrated in the design order.

Fig. 7B shows a characteristic of the diffraction efficiency resulting when a diffraction optical device shown in Fig. 7A is formed on a certain surface in an optical system.

In the following description, a value of the diffraction efficiency is defined by a ratio of an amount of diffracted light of each order to a total amount of light passing the diffraction optical device. For the brevity of explanation, however, light reflected by the boundary surface of a grating, etc. are not taken into consideration in calculating the value of the diffraction efficiency. In Fig. 7B, the horizontal axis represents wavelength and the



vertical represents diffraction efficiency.

The diffraction optical device comprises a grating with a pitch (period) of  $200\text{ }\mu\text{m}$  and a height of  $1\text{ }\mu\text{m}$ . The grating is made of a material having a refractive index  $n_d =$   
5  $1.513$  and the Abbe's number  $v_d = 50.08$ . The grating has a glazed structure as shown in Fig. 7A. The graph of Fig. 7B indicate the diffraction efficiency when the incident angle is zero (0 degree). This diffraction optical device is designed such that the diffraction efficiency in the  
10 wavelength range to be used is maximized for diffracted light of 1-order (indicated by a solid line in Fig. 7B). In other words, the design order is 1-order. Fig. 7B also represents the diffraction efficiency for light of orders around the design order (1-order  $\pm$  one order, i.e., 0- and 2-ordier indicated respectively by a broken line and a one-dot-chain line in Fig. 7B).

As shown in Fig. 7B, the diffraction efficiency for light of the design order is maximized at a certain wavelength (design wavelength) and is gradually lowered as  
20 the wavelength departs away from the design wavelength. Corresponding to a lowering of the diffraction efficiency for light of the design 1-order, diffracted light of other orders (0- and 2-orders, etc.) occurs and gives rise to unwanted flare light.

25 Japanese Patent Laid-Open No. 9-127322 discloses an

arrangement capable of suppressing a lowering of the diffraction efficiency at wavelengths other than the design wavelength. With this related art, high diffraction efficiency is realized over an entire visible range by selecting three kinds of materials and two different grating thicknesses in optimum combinations, and arranging a plurality of gratings in an adjacently superimposed relation with an equal pitch distribution.

Another arrangement capable of suppressing a lowering of the diffraction efficiency is disclosed in Japanese Patent Laid-Open No. 10-133149. Gratings are superimposed one above the other to have a two-layered sectional shape. High diffraction efficiency is realized over an entire visible range by optimizing the refractive indexes of materials of the two-layered gratings, the dispersion characteristics thereof, and the thickness of each grating.

According to the techniques disclosed in the above-cited publications, a diffraction optical device is made of two or more kinds of materials having different dispersion characteristics to reduce phase shifts occurred at wavelengths other than the design wavelength when light passes the diffraction optical device. As a result, the dependency of diffraction efficiency of the diffraction optical device upon wavelengths is greatly suppressed.

By arranging the diffraction optical device in a

refraction optical system, color aberration can be reduced to a large extent based on a physical phenomenon that the direction of dispersion of the diffraction optical device is opposed to that of a refraction optical device. It is also possible to compensate other aberrations by utilizing the above-mentioned effect that the diffraction optical device is able to function similarly to an aspherical lens.

In the diffraction optical device of the related art, however, the grating has a large depth and the dependency of diffraction efficiency upon the incident angle of light upon the diffraction optical device is increased. This raises a problem that the diffraction efficiency is greatly reduced depending upon layout of the diffraction optical device in the optical system.

Particularly, when an air layer is formed between two gratings made of materials different from each other as disclosed in Japanese Patent Laid-Open No. 11-223717, flexibility in selection of the grating materials is greater than that in the diffraction optical device disclosed in the above-cited Japanese Patent Laid-Open No. 10-133149, but the dependency of diffraction efficiency upon the incident angle of light is further increased.

#### SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a diffraction optical device capable of suppressing a lowering of diffraction efficiency due to the dependency thereof upon the incident angle of light, and an optical system including the diffraction optical device.

To achieve the above object, the present invention provides a diffraction optical device comprising a first diffraction element and a second diffraction element arranged adjacent to each other, wherein one of the first diffraction element and the second diffraction element has a positive power, the other has a negative power, and the first diffraction element reduces an incident angle of light upon the second diffraction element.

Further, the present invention provides a diffraction optical device comprising a first diffraction element and a second diffraction element arranged adjacent to each other, wherein the first diffraction element and the second diffraction element have blazed gratings having blazed shapes oriented in opposing directions, and the first diffraction element reduces an incident angle of light upon the second diffraction element.

Preferably, the first diffraction element and the second diffraction element are made of materials having dispersion characteristics different from each other.

Preferably, an air layer is interposed between the

first diffraction element and the second diffraction element, or the first diffraction element and the second diffraction element are arranged in an intimately contact relation.

Preferably, the light is a ray of off-axis primary  
5 light propagating through an optical system in which the diffraction elements are disposed.

Preferably, the diffraction elements are formed to have high diffraction efficiency for diffracted light of particular order over an entire wavelength range to be used  
10 in the optical system.

To achieve the above object, the present invention also provides an optical system comprising the diffraction optical device set forth above, and a refraction optical device.

Preferably, a wavelength range to be used in the  
15 optical system is a visible range.

Preferably, the optical system further comprises an iris, wherein a first diffraction element of the diffraction optical device has a positive power, a second diffraction  
20 element of the diffraction optical device has a negative power, and the diffraction optical device is arranged in a position nearer to an image than the iris.

Preferably, the optical system further comprises an iris, wherein a first diffraction element of the diffraction  
25 optical device has a negative power, a second diffraction

element of the diffraction optical device has a positive power, and the diffraction optical device is arranged in a position nearer to an object than the iris.

Further objects, features and advantages of the present invention will become apparent from the following description of the preferred embodiments with reference to the attached drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a sectional view of an optical system according to a first embodiment of the present invention, and Fig. 1B schematically shows the structure of a diffraction optical device;

Fig. 2 is a graph showing the diffraction efficiency of the diffraction optical device according to the first embodiment of the present invention;

Fig. 3 is a diagram showing the position of a pupil of the optical system and the incident angle of light upon a grating in the first embodiment of the present invention;

Fig. 4A is a sectional view of an optical system according to a second embodiment of the present invention, and Fig. 4B schematically shows the structure of a diffraction optical device;

Fig. 5 is a diagram showing the position of a pupil of

the optical system and the incident angle of light upon a grating in the second embodiment of the present invention;

Fig. 6A is a sectional view of an optical system according to a modification of the second embodiment of the present invention, and Fig. 6B schematically shows the structure of a diffraction optical device; and

Fig. 7A shows the structure of a single-layer grating of the related art, and Fig. 7B is a graph showing the dependency of diffraction efficiency of the single-layer grating upon wavelengths.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will be described below.

(First Embodiment)

Fig. 1A is a sectional view of an optical system according to a first embodiment of the present invention.

This embodiment represents the case where a diffraction optical device is employed in an extender for a photographic lens.

In Fig. 1A, numeral 101 denotes an overall optical system comprising a master lens 102, an extender 103, and an iris 107. Numeral 105 denotes an image plane and 104 denotes an optical axis. A diffraction optical device 106

is provided within the extender 103.

Fig. 1B schematically shows the structure of the diffraction optical device according to this embodiment. As shown in Fig. 1B, a first diffraction element 106a having a positive power (power  $\psi = 1/f$ :  $f$  is the focal length) and a second diffraction element 106b having a negative power are arranged adjacent to each other with an air layer 106c interposed between them. The first diffraction element 106a having a positive power is arranged on the side nearer to an object (i.e., on the light incident side of the air layer).

In Fig. 1B, grating portions of the two diffraction elements 106a, 106b are illustrated in enlarged scale for clearly showing an arrangement that two gratings (kinoforms) of the diffraction elements 106a, 106b have blazed shapes oriented in opposing directions.

As with the other lenses of the optical system 101, the diffraction optical device 106 has a structure rotationally symmetrical about the optical axis 104. As shown, the two diffraction elements 106a, 106b of the diffraction optical device 106 are each formed on a flat surface of a base plate, and the diffraction optical device 106 is joined to a lens 110. In the optical system of this embodiment, the incident angle of light upon the diffraction optical device 106 is increased as the image height increases.

Fig. 2 is a graph showing the diffraction efficiency of



the diffraction optical device. The graph of Fig. 2 indicates the diffraction efficiency resulting when the incident angle is 0, + 6 and - 6 degrees. The diffraction efficiency is represented by a percentage normalized based on the amount of light having passed the diffraction optical device. As seen from Fig. 2, the dependency of diffraction efficiency upon wavelengths is not the same and is asymmetrical between the case of the incident angle being + 6 degrees and the case of the incident angle being - 6 degrees. In this embodiment wherein the diffraction optical device 106 having the above-described construction is arranged in the refraction optical system, taking into account the incident angle of off-axis light upon the diffraction optical device 106, the first diffraction element 106a having a positive power is arranged on the side nearer to the object as shown in Fig. 1B. This arrangement is effective to reduce the incident angle of light upon the second diffraction element 106b having a negative power and arranged on the side nearer to the image plane.

The diffraction efficiency shown in Fig. 2 represents the cases where the incident angle  $\theta$  is set to 0, + 6 and - 6 degrees. When the incident angle is smaller than  $\pm 6$  degrees, the asymmetry in the dependency of diffraction efficiency upon wavelengths is reduced. Also, as the incident angle increases from  $\pm 6$  degrees, the asymmetry in

the dependency of diffraction efficiency upon wavelengths is increased. In the case where the incident angle of light upon the diffraction optical device 106 is positive, the incident angle of light upon the second diffraction element 106b on the exit side is reduced by the first diffraction element 106a on the entrance side, and therefore the asymmetry in diffraction efficiency between the positive incident angle and the negative incident angle is lessened as compared with the case where the incident angle of light upon the diffraction optical device 106 is negative.

In the arrangement of this embodiment, as shown in Fig. 3, the iris (pupil) 107, the diffraction optical device 106, and the image plane 105 are disposed successively in this order from the side nearer to an object 108. A ray of off-axis primary light 109 enters the diffraction optical device 106 at an angle shown in Fig. 3. The two diffraction elements 106a, 106b of the diffraction optical device 106 may be arranged such that the first diffraction element 106a having a positive power is located on the side nearer to the object as indicated by (a) in Fig. 3, or such that the second diffraction element 106b having a negative power is located on the side nearer to the object as indicated by (b) in Fig. 3. As described above in connection with Fig. 2, however, the dependency of diffraction efficiency upon wavelengths is not the same and is asymmetrical between the

case of the incident angle being positive and the case of the incident angle being negative. Accordingly, in this embodiment, the first diffraction element 106a having a positive power is arranged nearer to the object than the second diffraction element 106b having a negative power, as indicated by (a) in Fig. 3. By employing such an arrangement, the incident angle of light upon the second negative diffraction element 106b is reduced and a lowering of the diffraction efficiency is suppressed.

In this embodiment, the first diffraction element 106a having a positive power is made of an optical material 1 (having a refractive index  $n_d = 1.635$  and the Abbe's number  $v_d = 23$ ), and the second diffraction element 106b having a negative power is made of an optical material 2 (having a refractive index  $n_d = 1.5250$  and the Abbe's number  $v_d = 47.8$ ). The grating heights of the first and second diffraction elements 106a, 106b are set respectively to  $d_1 = 6.9 \times 10^{-3}$  (mm) and  $d_2 = 9.5 \times 10^{-3}$  (mm). Then, both the diffraction elements 106a, 106b are arranged adjacent to each other with the air layer interposed between them. The diffraction optical device is constructed as mentioned above, by way of example, in this embodiment, but the kinds of optical materials and the grating heights are not limited to the examples. Also, this embodiment has been described in connection with the case where the diffraction optical

device is arranged in an extender for a photographic lens. However, the present invention is not limited to that case, and similar advantages are obtained by applying the technique of this embodiment to any other optical system including a diffraction optical device.

(Second Embodiment)

Fig. 4A is a sectional view of an optical system according to a second embodiment of the present invention. In Fig. 4A, numeral 201 denotes an optical system including a diffraction optical device 202, an optical axis 203, an image plane 204, and an iris 205. This embodiment represents the case where the diffraction optical device is applied to a telephoto lens for a photographic lens.

Fig. 4B schematically shows the structure of the diffraction optical device according to this embodiment. As shown in Fig. 4B, a first diffraction element 202a having a negative power and a second diffraction element 202b having a positive power are arranged in an adjacently superimposed relation between two base plates with an air layer 202c interposed between both the diffraction elements.

In this second embodiment, as shown, the first diffraction element 202a having a negative power is arranged on the side nearer to an object. In Fig. 4B, grating portions of the first and second diffraction elements 202a, 202b of the diffraction optical device 202 are illustrated

in enlarged scale for clearly showing an arrangement that two gratings (kinoforms) of the first and second diffraction elements 106a, 106b have blazed shapes oriented in opposing directions.

5 Also, in this second embodiment, the dependency of diffraction efficiency upon wavelengths is asymmetrical, as shown in Fig. 2, between the case of the incident angle being positive and the case of the incident angle being negative.

10 In the arrangement of this embodiment, as shown in Fig. 5, the diffraction optical device 202, the iris (pupil) 205, and the image plane 204 are disposed successively in this order from the side nearer to an object 208. A ray of off-axis primary light 209 enters the diffraction optical device 15 202 at an angle shown in Fig. 5.

20 The two diffraction elements 202a, 202b of the diffraction optical device 202 may be arranged such that the second diffraction element 202b having a positive power is located on the side nearer to the object as indicated by (a) in Fig. 5, or such that the first diffraction element 202a having a negative power is located on the side nearer to the object as indicated by (b) in Fig. 5. Taking into account the fact that the dependency of diffraction efficiency upon wavelengths is asymmetrical between the case of the incident 25 angle being positive and the case of the incident angle

being negative as shown in Fig. 2, however, the incident angle of light upon the second positive diffraction element 202b is reduced and a lowering of the diffraction efficiency is suppressed in this embodiment by arranging the first  
5 diffraction element 202a having a negative power nearer to the object than the second diffraction element 202b having a positive power, as indicated by (b) in Fig. 5.

Thus, by arranging the diffraction elements 202a, 202b in the order indicated by (b) in Fig. 5, a lowering of the diffraction efficiency due to the dependency thereof upon  
10 the incident angle can be suppressed.

Fig. 6A shows a modification of the second embodiment. In Fig. 6A, numeral 301 denotes an optical axis, 303 denotes an iris, 304 denotes an image plane, and 305 denotes a  
15 diffraction optical device. The diffraction optical device 305 shown in Fig. 6A has a structure shown in Fig. 6B. More specifically, a first diffraction element 305a having a negative power and a second diffraction element 305b having a positive power are arranged within a lens device 306 in an  
20 adjacently superimposed relation with an air layer 305c interposed between both the diffraction elements.

The reason why the first diffraction element 305a having a negative power is arranged nearer to the object than the second diffraction element 305b having a positive  
25 power is the same as that in the second embodiment. While

the above description has been made in connection with a photographic lens, the present invention not limited to such an application. Also, the present invention is applicable to a diffraction optical device having no power.

5       According to the first and second embodiments, as described above, a lowering of the diffraction efficiency due to the dependency thereof upon the incident angle of light can be suppressed. It is therefore possible to realize a diffraction optical device having high diffraction efficiency, and an optical system including the diffraction optical device.

10       While the present invention has been described with reference to what are presently considered to be the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. On the contrary, the invention is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims. The scope of the following claims is to be accorded the broadest  
15  
20       interpretation so as to encompass all such modifications and equivalent structures and functions.

[illegible]

**Abstract**

[illegible][illegible]

**Abstract**

[illegible]



4. A diffraction optical device according to any one of Claims 1 to 3, wherein an air layer is interposed between said first diffraction element and said second diffraction element.

5. A diffraction optical device according to any one of Claims 1 to 4, wherein the light is a ray of off-axis primary light propagating through an optical system in which said diffraction elements are disposed.

6. A diffraction optical device according to Claim 5, wherein said diffraction elements are formed to have high diffraction efficiency for diffracted light of particular order over an entire wavelength range to be used in said optical system.

7. An optical system comprising a diffraction optical device according to any one of Claims 1 to 6, and a refraction optical device.

8. An optical system according to Claim 7, wherein a wavelength range to be used in said optical system is a visible range.

9. An optical system according to Claim 7 or 8,

further comprising an iris, wherein a first diffraction element of said diffraction optical device has a positive power, a second diffraction element of said diffraction optical device has a negative power, and said diffraction optical device is arranged in a position nearer to an image than said iris.

10. An optical system according to Claim 7 or 8, further comprising an iris, wherein a first diffraction element of said diffraction optical device has a negative power, a second diffraction element of said diffraction optical device has a positive power, and said diffraction optical device is arranged in a position nearer to an object than said iris.

Figure 1 consists of 12 histograms arranged in two rows of six. The top row is labeled 'Iteration' and the bottom row is labeled 'Iteration'. The x-axis for all histograms is 'Number of non-zero elements' ranging from 0 to 1000. The y-axis is 'Frequency' ranging from 0 to 100. The distributions are roughly bell-shaped and centered around 500.

FIG. 1A

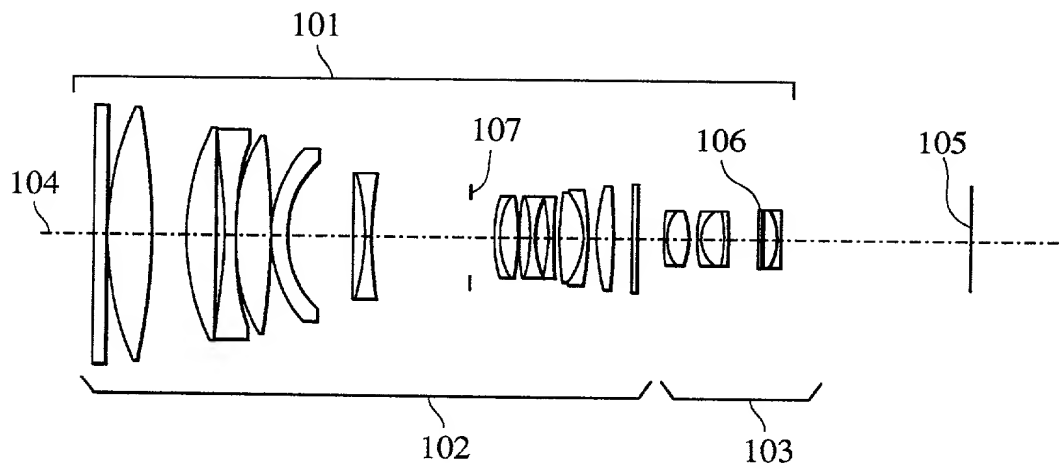


FIG. 1B

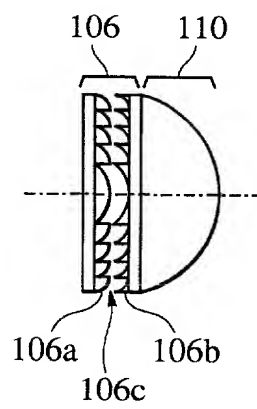
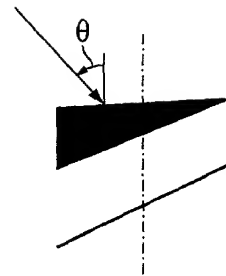
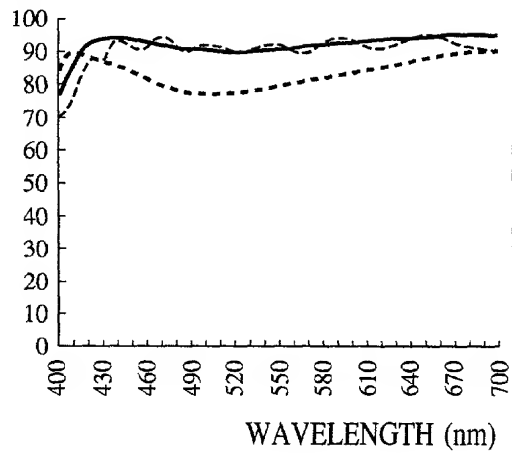


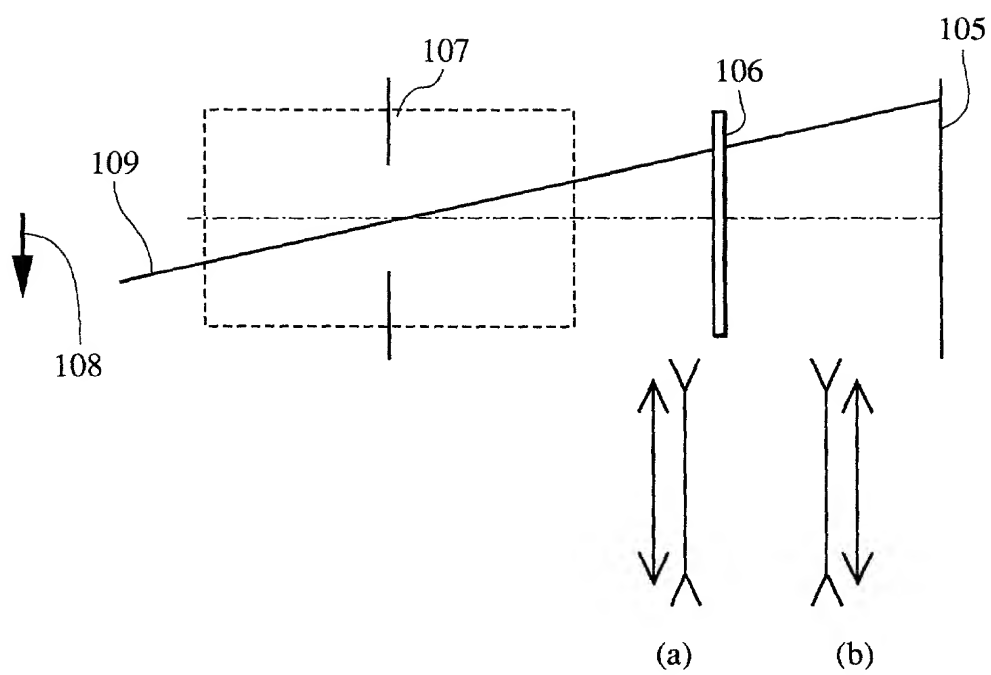
FIG. 2

DIFFRACTION  
EFFICIENCY (%)



	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2
--	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	---

FIG. 3



2007-07-20 10:53:50

FIG. 4A

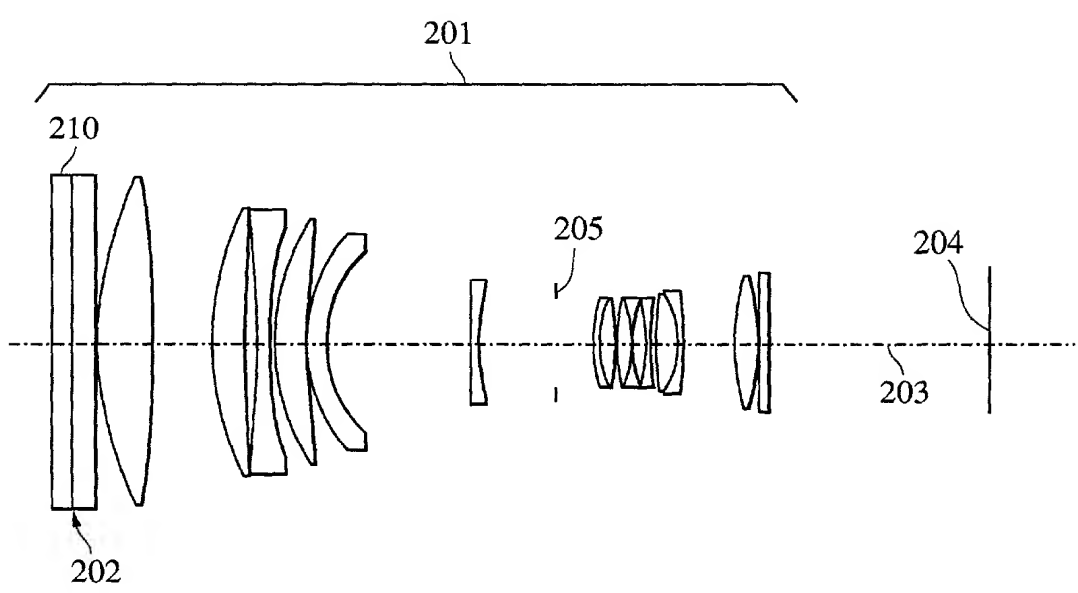


FIG. 4B

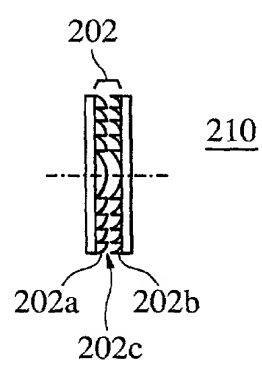
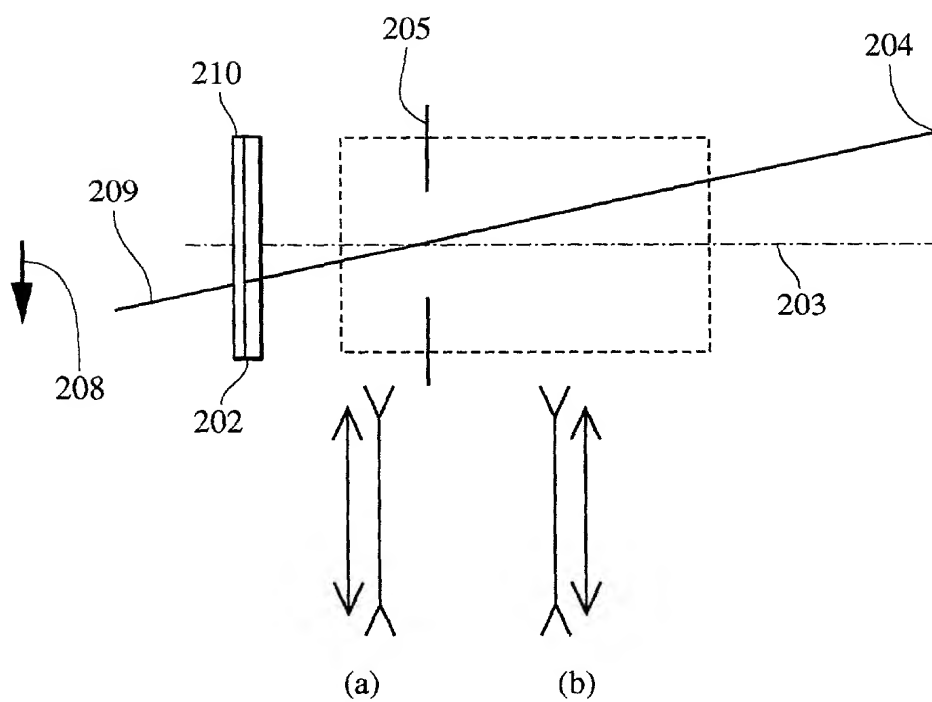


FIG. 5





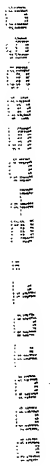
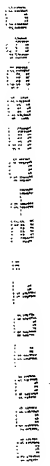
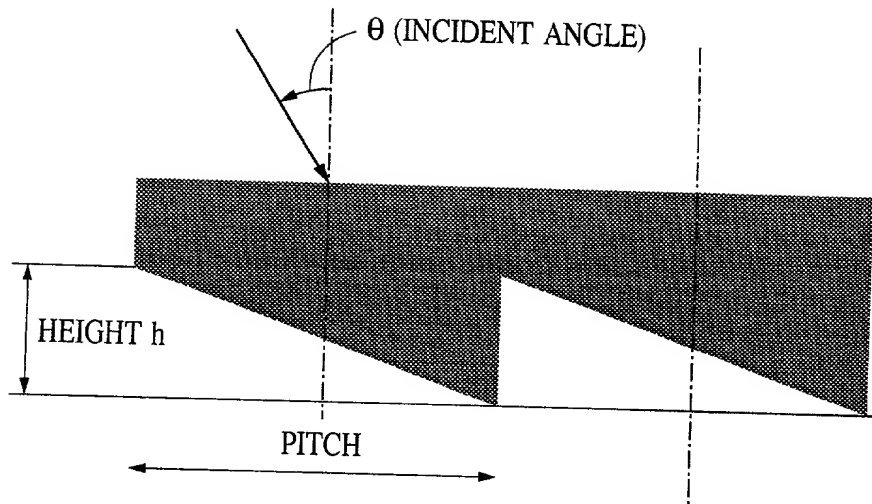
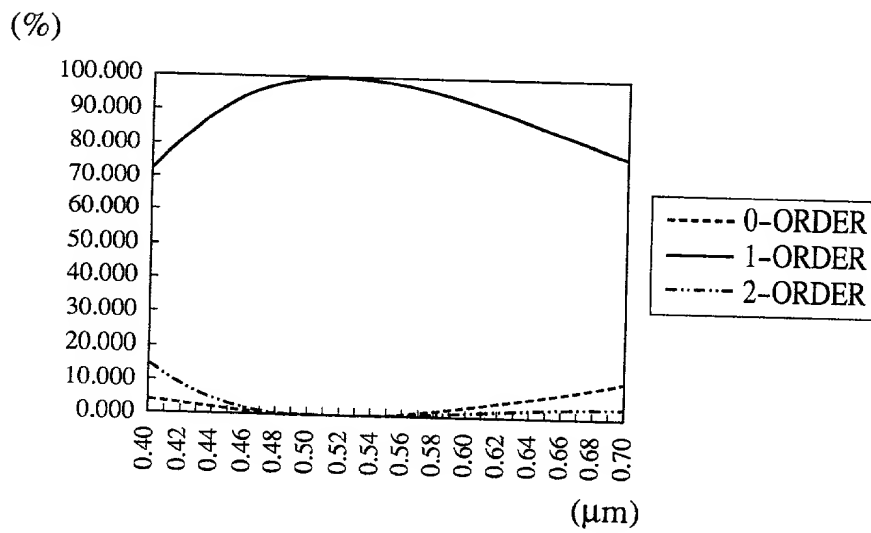


FIG. 7A



( REFRACTIVE INDEX  $n_d=1.513$ , ABBE'S NUMBER  $v_d=50.08$  )

FIG. 7B



**COMBINED DECLARATION AND POWER OF ATTORNEY  
FOR PATENT APPLICATION**  
(page 1)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled DIFFRACTION OPTICAL DEVICE AND OPTICAL SYSTEM INCLUDING SAME  
the specification of which ☒ is attached hereto. ☐ was filed on \_\_\_\_\_ as United States Application No. or PCT International Application No. \_\_\_\_\_ and was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b), of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designates at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed:

<u>Country</u>	<u>Application No.</u>	<u>Filed (Day / Mo. / Yr.)</u>	<u>(Yes / No)</u> <u>Priority Claimed</u>
Japan	290057/1999(Pat.)	12/October/1999	Yes

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or §365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

<u>Application No.</u>	<u>Filed (Day/Mo./Yr.)</u>	<u>Status</u> <u>(Patented, Pending, Abandoned)</u>

I hereby appoint the practitioners associated with the firm and Customer Number provided below to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to the address associated with that Customer Number:

**FITZPATRICK, CELLA, HARPER & SCINTO**  
Customer Number: 05514

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of Sole or First Inventor Shuichi Kobayashi  
Inventor's signature Shuichi Kobayashi  
Date Shuichi Kobayashi Citizen/Subject of Japan  
October 4, 2000  
Residence Kanagawa, Japan  
Post Office Address CANON KABUSHIKI KAISHA  
3-30-2, Shimomaruko, Ohta-ku, Tokyo, Japan